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Biometric Advisory System to Analyze a User's Post-Disaster Stress Management

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Abstract

This article describes in detail the developed Biometric Advisory System to Analyze a User's Post-Disaster Stress Management. The system is based on algorithms developed by the authors. The system was developed and fine-tuned in the course of the Android project. The authors based their Advisory System on the presumption that, by assigning a user post-disaster stress self-assessment and then looking for the interdependency with the user's biometric parameters (heart rate, blood pressure, pupil, skin conductance and humidity; body, forehead, nose, left and right cheek, chin, left palm and left middle finger temperatures, etc.) recorded at that time, it is possible to determine the link rather accurately. In other words, a user internally senses the actual rating of his/her personal post-disaster stress. Their existing experiences and intuition give users a rather accurate indication about their post-disaster stress. A sufficient number of studies have been performed worldwide and quite many systems have been developed that apply biometric technologies to establish different human states of stress. The global innovative aspects of the Biometric Advisory System, developed by the authors, are primarily that it determines the level and symptoms of the post-disaster stress, carrying out multivariant design of a disaster stress management life cycle (emergency response, recovery, prevention/mitigation and preparedness/readiness) and alternative recommendations applicable to a specific user (on ways to reduce post-disaster stress), performs a multiple criteria analysis of it and selects the ten most rational ones (disaster stress management life cycle and tips) for that user. The Impact of Event Scale-Revised (IES-R) is used as a self-assessment instrument to determine the symptoms of post-disaster stress stress and to draw up recommendations. Also, the users were assessed with the IES-R in order to define the significance of posttraumatic stress symptoms.

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1. Introduction

Based on the analysis of existing neural networks (Liu et al. 2014, Eisenbies et al. 2007, Kong-A-Siou et al. 2013), early warning (Van Veen 2014, Krzhizhanovskaya et al. 2011, Alfieri et al. 2012, Borga et al. 2014), fuzzy (Royston et al. 2013) expert (Kou et al. 2014, Karnib et al. 2002) and decision support (Hubbard et al. 2014) systems, Impact of Event Scale (Arnberg et al. 2014, Shooshtary et al. 2008, Dancause et al. 2011, Keskinen-Rosenqvist et al. 2011, Heir et al. 2010, Chen et al. 2011), as well as on the long experience of the article's authors (Kaklauskas et al. 1999, 2010, 2011a,b, 2013, etc.) and in order to determine most efficient tips of stress resilience a Biometric Advisory System to Analyze a User's Post-Disaster Stress Management consisting of an equipment subsystem, database, database management system, model-base, model-base management system and user interface was developed (see Figure 1). The Biometric Advisory System was developed and fine-tuned in the course of the Android (Academic Network for Disaster Resilience to Optimise educational Development) project. Android project is being carried out with the financial assistance of the EU Life Long Learning programme, under the Erasmus networks action. ANDROID is concerned with what resilience is, what it means to society, and how society might achieve greater resilience in the face of increasing threats from natural and human induced hazards.

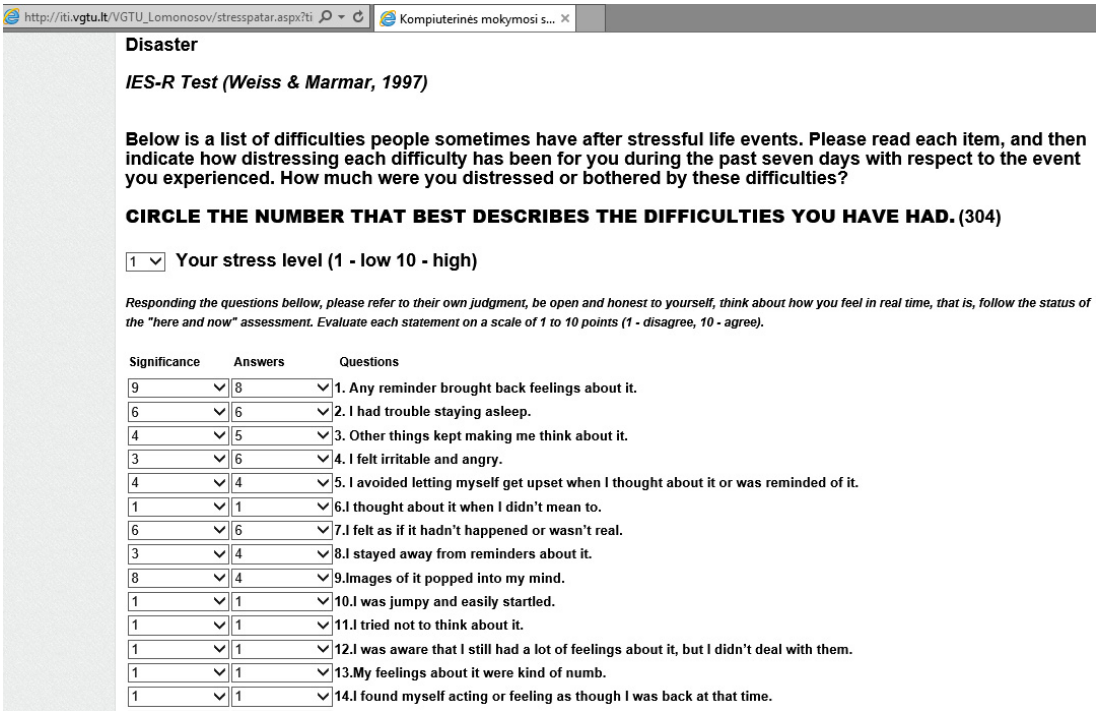

Figure 1. Fragment of Biometric Advisory System to Analyze a User's Post-Disaster Stress Management

Some examples of these worldwide systems will be briefly described below.

Traditional empirical correlations and models have found insufficient to predict the flooding velocity accurately mainly because there are many kinds of random packings which exhibit different characteristics (Liu et al. 2014). Liu et al. (2014) propose a novel data-driven modeling method, i.e. ensemble least squares support vector regression (ELSSVR), to construct a unified correlation for prediction of the flooding velocity for packed towers with random packings. The flooding data are first clustered into several classes by the fuzzy c-means clustering algorithm. Then,

several single LSSVR models can be trained using each sub-class of samples to capture the special characteristics. Moreover, a weighted least squares approach is adopted to integrate these single LSSVR models. Consequently, the ELSSVR model can extract the feature information of flooding data effectively and improve the prediction performance. The proposed ELSSVR method is applied to construct a unified correlation for prediction of the flooding velocity in randomly packed towers. The obtained results for several kinds of random packings demonstrate that the ELSSVR-based correlation can obtain better prediction performance, compared with the traditional semi-empirical correlations and artificial neural networks-based models (Liu et al. 2014).

Krzhizhanovskaya et al. (2011) present a prototype of the flood early warning system (EWS) developed within the UrbanFlood FP7 project. The system monitors sensor networks installed in flood defenses (dikes, dams, embankments, etc.), detects sensor signal abnormalities, calculates dike failure probability, and simulates possible scenarios of dike breaching and flood propagation. All the relevant information and simulation results are fed into an interactive decision support system that helps dike managers and city authorities to make informed decisions in case of emergency and in routine dike quality assessment. In addition to that, a Virtual Dike computational module has been developed for advanced research into dike stability and failure mechanisms, and for training the artificial intelligence module on signal parameters induced by dike instabilities. This paper describes the UrbanFlood EWS generic design and functionality, the computational workflow, the individual modules, their integration via the Common Information Space middleware, and the first results of EWS monitoring and performance benchmarks (Krzhizhanovskaya et al. 2011).

Preparedness towards natural hazards is a key factor in the reduction of their impact on the society. Recent international initiatives are fostering the development of a culture of risk prevention and the promotion of early warning systems. Numerical weather predictions have become the basis of several flood-related warning systems, enabling the detection of hazardous events with sufficient lead-time to prepare effective emergency and response plans (Alfieri et al. 2012). The objective of Alfieri et al. (2012) research is to review current European operational warning systems for water-related hazards induced by severe weather conditions. In details, it includes systems for detecting surface water flooding, flash floods, debris flows, mud flows, rainfall-induced landslides, river floods and coastal floods (Alfieri et al. 2012).

To improve the efficiency of storm drainage networks, many local authorities have invested in network upgrading projects. Many upgrading alternatives can be generated for a given problem. It is the designer's responsibility to choose among the available alternatives. The main objective of the upgrade designs is to reduce flooding of urban areas during extreme storm events (Karnib et al. 2002). Karnib et al. (2002) presents an expert system based on fuzzy inference to evaluate the sensitivity of urban areas to network failure. The produced results allow the designer to classify various network upgrading alternatives according to their impacts on urban areas and to introduce this order in a multi-criteria method. A practical application of the expert system is given and its applicability is discussed (Karnib et al. 2002).

Natural disatsters are one of the types of traumatic stressors, which may cause symptoms relevant to posttraumatic stress or disorder itself within individuals exposed to that stressor. The widely used measure to determine posttraumatic stress symptoms is the Impact of Eve Scale - Revised (IES-R). Reviewed literature inclines that IES-R is used to measure individual’s psychological reactions to various natural disasters (such as tsunami, earthquake, floods and etc.) as wells as within various cultural context (European countries, Haiti and etc.).

Arnberg et al. (2014) evaluated the properties of Swedish versions of self-report measures of posttraumatic stress (PTSD), with emphasis on the Impact of Event Scale-Revised (IES-R). Survey data from adult survivors 1, 3, and 6 years after the 2004 Indian Ocean tsunami (n = 1506) included the IES-R (from which the IES-6 was derived) and the 12-item General Health Questionnaire (GHQ-12). In conclusion, the Swedish IES-R and PCL are sound measures of chronic PTSD, and the findings illustrate important temporal aspects of PTSD assessment. In summary, the findings provide support for the use of the IES-R and PCL as sound measures of chronic PTSD. In addition, in the context of a low prevalence of PTSD and the uncertainty that arises with few PTSD cases, the findings provide preliminary evidence that the IES-R proved reliable across assessments to detect chronic forms of PTSD (Arnberg et al. 2014).

Shooshtary et al. (2008) evaluated the effectiveness of cognitive behavioral therapy (CBT) among adolescents exposed to the 2004 earthquake in Bam, Iran. Four months after the earthquake, 135 adolescents as a case group and 33 adolescents as a comparison group were evaluated with the Impact of Event Scale Revised (IES-R). Two

therapists were trained in CBT in 3-day classes according to a manual provided by mental health services. After conducting CBT in the case group, both groups were evaluated again with IES-R. The severity of posttraumatic stress symptoms significantly decreased among the subjects given CBT in the case group. The improvement in posttraumatic stress symptoms was attributable to improvement in each of three-symptom categories (intrusion, avoidance, and arousal) and in the total score of posttraumatic stress ($p < .05$). The findings demonstrate the efficacy of CBT in alleviating posttraumatic stress symptoms among adolescents after a catastrophic disaster (Shooshtary et al. 2008).

Dancause et al. (2011) assessed women's psychological reaction to the storm in the first questionnaire using a validated French version of the Impact of Event Scale — Revised (IES-R). This 22-item scale, widely used for assessing distress following trauma exposure, describes symptoms from three categories relevant to post-traumatic stress: Intrusive Thoughts, Hyperarousal, and Avoidance. Participants responded on a 5-point Likert scale, from "Not at all" to "Extremely," the extent to which each behavior described how they felt over the preceding seven days. Items were written to reflect symptoms relative to the ice storm. The total score was used in analyses (Dancause et al. 2011).

The Impact of Events Scale Revised (IES-R) with 22 items was used to assess posttraumatic symptoms. The degree of distress in the last week in response to a specific stressor is rated for each item on a five-point scale, ranging from 0=not at all to 4=extremely. In this study, the stated stressor was the tsunami. The Swedish translation has been used in several studies. The Cronbach's alpha for the present study group was .95 (Keskinen-Rosenqvist et al. 2011).

Heir et al. (2010) examined posttraumatic stress symptom clusters associations with psychopathology and functional impairment in 899 Norwegian survivors of the 2004 South-East Asia tsunami six months post-disaster. Posttraumatic stress symptoms were assessed with the Impact of Event Scale-Revised (IES-R) with intrusion, avoidance, and hyper-arousal subscales. For criterion variables, Heir et al. (2010) used 10 indicators of psychopathology and functional impairment, e.g. having mental health problems, seeing mental health professionals, and use of medication or sick leave. Hyper-arousal had stronger correlations than avoidance with all criterion variables (p values < 0.001) and stronger correlations than intrusion with seven of the 10 criterion variables (p values < 0.01). Also, intrusion had stronger correlations than avoidance with seven of 10 criterion variables (p values < 0.05). Thus, Heir et al. (2010) findings indicate that symptoms of hyperarousal may be more closely linked to psychopathology and functional impairment than other symptoms of posttraumatic stress following a sudden onset, short duration, natural disaster event.

The purpose of Chen et al. (2011) study was to validate the Impact of Event Scale-Revised (IES-R) for adolescents who had experienced the floods and mudslides caused by Typhoon Morakot in Taiwan. The internal consistency, construct validity, and criteria validity of the instrument were examined. Principal component analysis followed by an oblique rotation was used to derive a three-factor solution. These factors were labeled intrusion, hyperarousal, and avoidance; all three factors together accounted for 58.1% of the variance. The total Cronbach's alpha of 0.94 reflected the good internal consistency of the instrument. With reference to diagnosis of posttraumatic stress, the IES-R cutoff point for posttraumatic stress was 19 of 20 with a sensitivity of 85.7% and specificity of 84.1%. In conclusion, the IES-R can be used as a reliable and valid instrument when evaluating psychological distress among adolescents who have experienced a natural disaster, such as flooding and mudslides (Chen et al. 2011).

As though the IES-R has strong psychometric properties (the internal consistency reliability and convergent validity (King et al. 2009) and is applied to measure symptoms of posttraumatic stress to various natural disasters and within various cultural context, so this scale was chosen to use in Biometric Advisory System.

2. Biometric Advisory System to Analyze a User's Post-Disaster Stress Management

The presentation of information needed for decision making in Biometric Advisory System to Analyze a User's Post-Disaster Stress Management may be in conceptual (digital (numerical), textual, graphical (diagrams, graphs, drawing, etc.), augmented reality, photographical, sound, visual (video)) and quantitative forms. Thus, quantitative information presentation involves criteria systems and subsystems, units of measurement, values and initial weights

fully defining the recommendations provided. Conceptual information means a conceptual description of the alternative tips, the criteria and ways of determining their values and weights, etc.

In this way, Biometric Advisory (BA) System enables the decision maker to get various conceptual and quantitative information on user's post-disaster stress management from a database and a model-base allowing him to analyze the above factors and make an efficient solution.

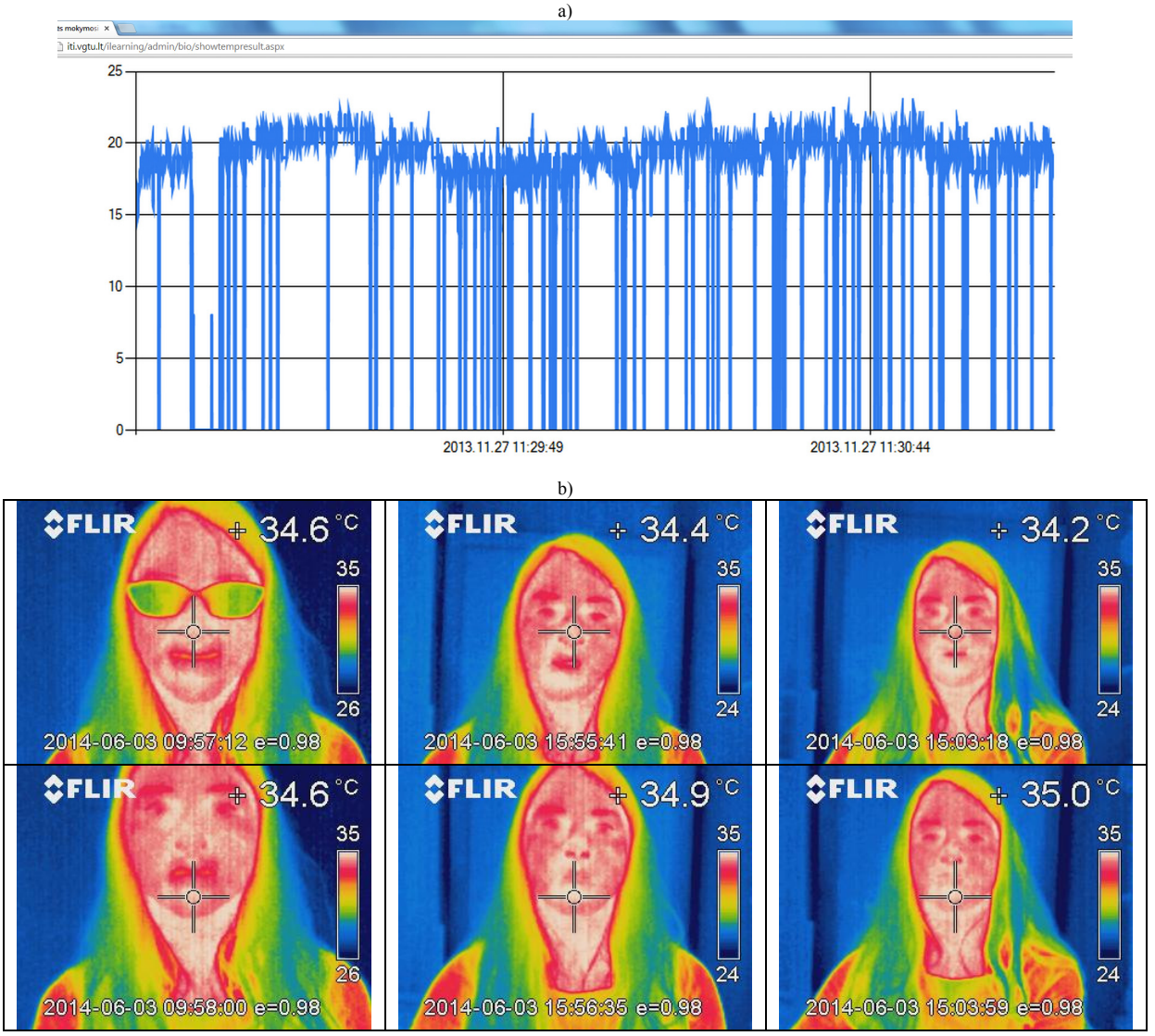

Figure 2. Fragment of user's biometric database: a) a person's pupil size, eye blink frequency, b) a person's face temperature

BA system has a relational database structure when the information is stored in the form of tables. These tables contain quantitative and conceptual information. Each table is given a name and is saved in the computer external memory as a separate file. Logically linked parts of the table make a relational model. The following tables make BA system database:

- Initial data tables. These contain general facts about the user's post-disaster stress.

- Tables assessing a user's post-disaster stress management solutions.
- Tables assessing a user's post-disaster stress management tips.
- Tables of multiple stress management solutions design.
- Tables of multi-tips design.
- Correlation tables between the user's posttraumatic stress and the parameters of the user's biometrical parameters (heart rate, blood pressure, pupil, skin conductance and humidity; body, forehead, nose, left and right cheek, chin, left palm and left middle finger temperatures, etc.);
- User's biometric database (see Figure 2).
- Recommendations tables.

A sufficient amount of studies worldwide prove an interrelation between a person's pupil size, eye blink frequency and emotional stress. Stress and anxiety tend to increase a person's pupil size and blink rate. Therefore, the temporal increase in eye blink frequency and pupil size can already be used as a measure of post-disaster stress (see Figure 2a).

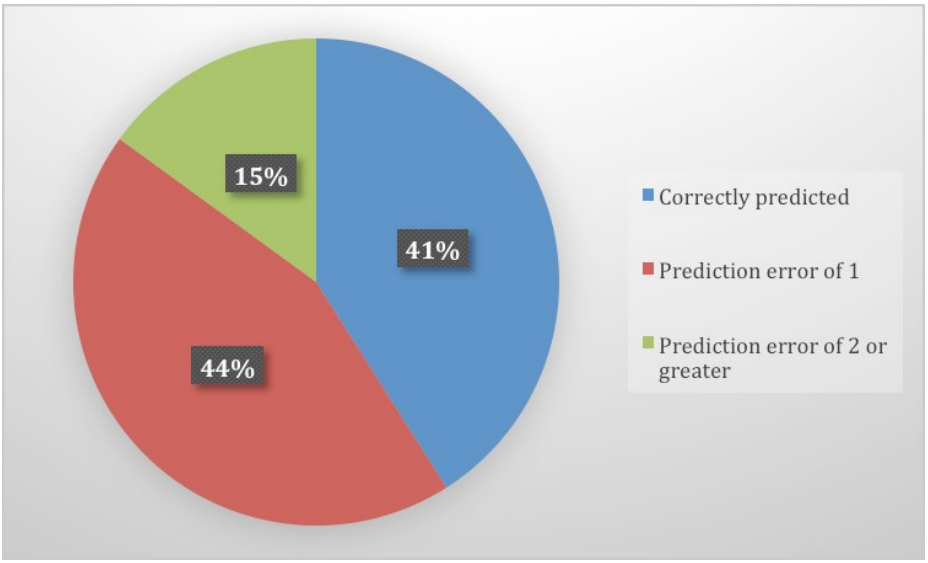

Figure 3. Precision of a subject's post-disaster stress level prediction

Figure 3 illustrates the precision of a subject's post-disaster stress level prediction by applying Biometric Advisory System to Analyze a User's Post-Disaster Stress Management. Blue colour represents the correctly predicted post-disaster stress level (41%), green colour represents those post-disaster stress level predictions, that had an error of one point (44%), red color represents the post-disaster stress level predictions, that had an error of two or greater points (15%).

The collection, processing and presentation of information for a database in the computer acceptable form is a complicated time-consuming process. The information collected in a database should be reliable, fully describing user's post-disaster stress management as well as enabling BA system to perform an efficient user's post-disaster stress multi-tips and management solutions (social, ethical, psychological, emotional, religious, ethnic, technical, technological, economic, legal/regulatory, integrated, etc.) design and multiple criteria analysis.

A lot of data had to be processed and evaluated in carrying out multivariant design of a disaster stress management life cycle (emergency response (rescue efforts, fire fighting, emergency medical assistance and an evacuation procedure, stress management for emergency response), recovery (rehabilitation and disaster-resilient reconstruction, land use planning, industrial rehabilitation planning and livelihood support, stress management for recovery), prevention/mitigation (utilisation of seismic resistant technology for rebuilding or retrofitting, the construction of dikes, replanting of mangroves, forestation and the construction and operation of meteorological

observation systems to help prevent and mitigate damage in the event of an earthquake, flood, landslide or storm) and preparedness/readiness (hazard maps, food and material stockpiling as well as the preparation of emergency kits, all vital factors that help to minimise the impact of a disaster, stress management for preparedness/readiness). The number of feasible alternatives can be as large as million. Each of the alternatives may be described from various perspectives (social, cultural, ethical, psychological, emotional, religious, ethnic, technical, technological, economic, legal/regulatory and other aspects), e.g. by conceptual and quantitative information. The problem arises how to perform computer-aided design of the alternative variants based on this enormous amount of information. To solve this problem a method of multiple criteria multivariant project (disaster stress management) life cycle design was developed (Kaklauskas 1999). According to the above method multiple criteria multivariant design is carried out in 5 stages.

The users seeking the efficient post-disaster stress management should provide in tables of initial data exact information about post-disaster stress, resilience aims and significance as well as about micro, meso and macro environment.

Based on various sources of information the recommendations presenting some interest to the user as well as some general facts, a system of criteria, their types (quantitative and qualitative), units of measurement and the range of value estimation are determined. The wider the range of estimating the values and weights of the criteria the more accurate analysis may be done.

Uniform types of relational tables have been chosen to facilitate entering of appropriate data into the database. Such unified database also make it possible easily correct and introduce new information as well as efficiently carrying out computation.

The above tables are used as a basis for working out the matrices of decision making. These matrices, along with the use of a model-base and models, make it possible to perform multi-tips design and multiple criteria evaluation resulting in the selection of most beneficial recommendations.

In order to design and realise an effective user's post-disaster stress management tips the alternatives available should be analysed.

Based on the above tables of multi-tips tips design possible user's post-disaster stress management variants are being developed. When using a method of multi-tips design suggested by the authors until million alternative user's post-disaster stress management tips may be obtained. These tips are checked for their capacity to meet various requirements. Those which can not satisfy these requirements raised are excluded from further consideration. In designing a number of variants of user's post-disaster stress management the problem of significance compatibility of the criteria arises. In this case, when a complex evaluation of the alternatives is carried out the value of a criterion significance is dependent on the overall criteria being assessed as well as on their values and initial weights.

The Model-base consists of the following models:

- model to determine the correlation between the user's posttraumatic stress and the parameters of the user's biometrical parameters (heart rate, blood pressure, pupil, skin conductance and humidity; body, forehead, nose, left and right cheek, chin, left palm and left middle finger temperatures, etc.) (Model for Dependence Analysis);
- model to evaluate the user's posttraumatic stress;
- model to determine initial criteria weights (data and user characteristics and recommendations) using **expert** evaluation methods;
- model to determine criteria weights;
- module to develop the model of a user's posttraumatic stress state;
- model to design multi-variant recommendations;
- model to design multi-variant stress management solutions;
- model to analyze multiple criteria and to prioritize recommendations and stress management solutions;
- model to determine the utility degree of recommendations and stress management solutions;
- model to deliver the recommendations and stress management solutions.

3. Conclusions

The Biometric Advisory System to Analyze a User's Post-Disaster Stress Management was developed in order to decrease the user's post-disaster stress. The plans for the next stage of the System's development involves

integrating this system with other biometric (voice stress analysis, etc.) systems, which have also been developed by the authors (Kaklauskas et al. 2010, 2011a,b, 2013, etc.) herein. Such an integration of intelligent and biometrics systems would provide even better assessments of the user's post-disaster stress and the submissions of specific recommendations to them.

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